

## DISCUSSION

### Introduction

The Stellwagen Bank National Marine Sanctuary Mapping Project is a cooperative effort of the U.S. Geological Survey and the National Oceanic and Atmospheric Administration, with support from the University of New Brunswick and the Canadian Hydrographic Service. The multibeam echo sounder survey was conducted on four cruises over a two-year period from the fall of 1994 to the fall of 1996. This map shows one of a series of 18 quadrangles (see location map) in which sea floor depth information is depicted in sun-illuminated (or shaded relief) view at a scale of 1:25,000, with topographic contours overlain in blue. The image shown here uses a sun elevation angle of 45 degrees above the horizon from an azimuth of 350 degrees and a vertical exaggeration of four times. In effect, topographic relief is enhanced by having the sun illuminate the sea floor from a position 10 degrees west of north, so that shadows are cast on the southern flanks of seabed features. Some features in the image are artifacts of data collection. They are especially noticeable where the seabed is smooth, and they include small highs and lows and unexplained-looking features and patterns that are oriented parallel or perpendicular to survey tracklines. For a depiction of the topographic contours alone, and for an explanation of survey and topographic data processing methods, see the companion map by Valentine and others (1997). Topographic contour maps of all 18 quadrangles in the map series are available on a CD-ROM in EPS, PS, Arc export, and PDF file formats (Valentine and others, 1998). Blank areas represent places where no data exists.

### Regional seabed features

The major topographic features depicted in the map series were formed by glacial processes. In broad terms, these features are interpreted here to represent a glacial history that developed in several stages. Ice containing rock debris moved across the region, scolding its surface and depositing sediment to form the large basins, banks, ridges, and valleys. Many other features observed here represent the later stages of deglaciation. They are the result of processes at work when much of the area was covered by stationary retreating ice, and when at the same time small valley glaciers and ice falls were active in and near areas of high topographic relief. The sea masked the region formerly occupied by ice, and seabed features were partly eroded and some

new sedimentary deposits formed. Today, the sea floor is modified mainly by strong southwestward-flowing bottom currents caused by storm winds from the northeast. These currents erode sediments from the shallow banks and transport them into the basins. With time, the banks affected by these currents become coarser, as sand and mud are removed and gravel remains, and the western flanks of the banks, as well as adjacent basins, are built up by deposits of mud and sand.

### Quadrangle 1 features

The northeastern part of Quadrangle 1—extending from the southeast corner to the north-central edge of the map area—lies in the southwestern part of Stellwagen Bank. The sea floor here is smooth and flat, except gently undulating through water depths of approximately 55 to 65 m. The sea floor in the remainder of the quadrangle consists of gravel banks and sandy basins, which are quite distinct in the west but which are increasingly covered with mud as water depth increases toward Stellwagen Basin in the east. In the western and west-central parts of the quadrangle, the sea floor is characterized by prominent, southeast-trending gravel banks that are separated by small basins. The orientation of these features parallels the movement direction of glacial ice. Similar features are present in the adjacent Quadrangle 4 to the north (Valentine and others, 2000). The banks lie in 15 to 35 m of water and have a relief of 5 to 10 m. Their surfaces are covered with gravel, including boulder piles and ridges that have a relief of up to 5 m and that resemble ebb-line bars and gravel deposited by moving water within stationary glacial ice and end moraines (deposits of rock debris piled up at the forward edges of moving ice). Ebbes are present on the bank tops and flanks (42°08.9' N, 70°34.4' W; 42°09.8' N, 70°35.9' W). Probable end moraines are located on the banks and are oriented northward, across the regional grain (42°09.9' N, 70°34.9' W; 42°07.8' N, 70°30.4' W). The gravel banks are partly covered in places by a thin veneer of sand. Shallow, irregularly shaped depressions in the sea floor adjacent to the gravel banks possibly outline the former locations of large masses of melting glacial ice (42°10.5' N, 70°33.3' W; 42°09.8' N, 70°34.4' W).

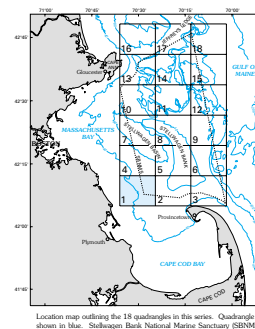
The basins that lie between the gravel banks are covered by sand and gravelly sand. One basin at 40 m (and greater) water depth has a smooth sand floor (42°11.6' N, 70°34.4' W), whereas a basin of intermediate depth (35 to 40 m) is rougher and is floored with coarser sand and gravel (42°10.9' N, 70°34.8' W). The large,

approximately 2-km-wide basin centered at 42°07.9' N, 70°34.6' W is covered by sand and gravel and is marked by numerous northeast-trending boulders. In the extreme southwestern part of the quadrangle, sand deposits in the form of elongated ridges trending northeast (42°05.5' N, 70°34.8' W) and very small rounded features (42°05.4' N, 70°33.5' W) in 20 to 30 m water depth are finer grained than the sand in adjacent areas of the seabed.

The sea floor that lies between the area of basins and gravel banks in the western part of the quadrangle and the muddy Stellwagen Basin in the eastern and northeastern part is characterized by shallow basins and gravel banks of low relief that are partly buried by sand and muddy sand (42°06.3' N, 70°27.2' W; 42°11.0' N, 70°31.0' W). A low, round hill composed of cobbles and boulders, which is almost completely covered with mud, lies in the northeastern part of the quadrangle at 60 to 65 m water depth (42°11.8' N, 70°27.1' W). Within the region of partly buried banks and basins are scattered exposures of coarse-grained sand that are partly covered with deposits of fine-grained sand (42°05.3' N, 70°29.8' W; 42°11.4' N, 70°32.7' W). The edges of the fine line, where they breasted the coarse exposures, are curved and sharply defined, as if formed by bottom currents. It is possible that the coarse deposits have been exposed by bottom currents that have eroded the coarsening fine layer. Similar features are present in the adjacent Quadrangle 4 to the north.

### REFERENCES CITED

- Valentine, P.C., Baker, J.L., Unger, T.S., and Roworth, E.T., 1997, Sea floor topography of Quadrangle 1 in the Stellwagen Bank National Marine Sanctuary off Boston, Massachusetts: U.S. Geological Survey Open-File Report 97-502, scale 1:25,000.  
Valentine, P.C., Baker, J.L., Unger, T.S., and Poloni, C., 1998, Sea floor topographic map and perspective-view imagery of Quadrangles 1-18, Stellwagen Bank National Marine Sanctuary off Boston, Massachusetts: U.S. Geological Survey Open-File Report 98-138, 1 CD-ROM.  
Valentine, P.C., Unger, T.S., and Baker, J.L., 2000, Sun-illuminated sea floor topography of Quadrangle 4 in the Stellwagen Bank National Marine Sanctuary off Boston, Massachusetts: U.S. Geological Survey Geologic Investigations Series Map I-2704, scale 1:25,000.



Location map outlining the 18 quadrangles in this series. Quadrangle 1 shown in blue. Stellwagen Bank National Marine Sanctuary (SBNS) boundary indicated by dashed line. Bathymetric contours in meters.

# SUN-ILLUMINATED SEA FLOOR TOPOGRAPHY OF QUADRANGLE 1 IN THE STELLWAGEN BANK NATIONAL MARINE SANCTUARY OFF BOSTON, MASSACHUSETTS

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